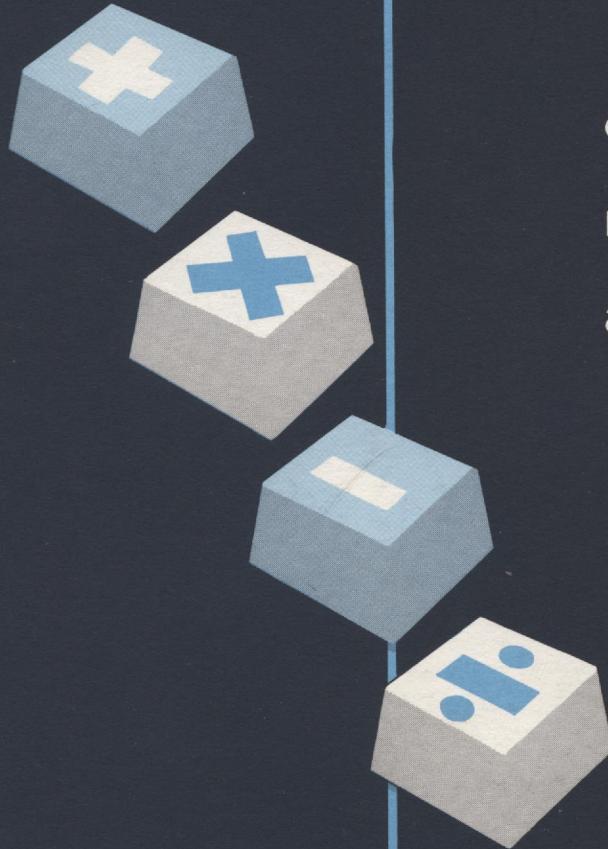


An experiment conducted
at Memorial School
Cedar Grove, New Jersey
by Dr. Howard F. Fehr,
Head of the Department of Teaching
of Mathematics, Teachers College,
Columbia University, New York.



can children
really enjoy
arithmetic?

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B-243

Printed in U.S.A.

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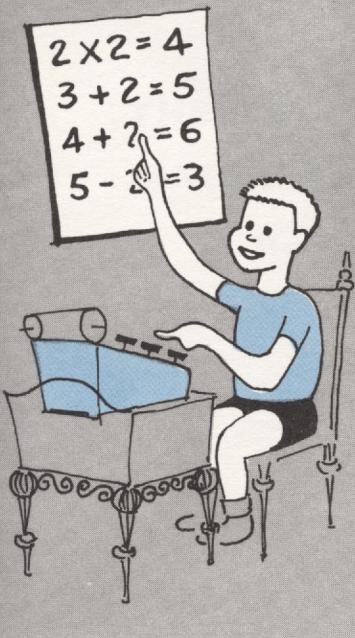
introduction

The essential purpose of the experiment described in the following report was to determine the degree of improvement in computation and reasoning ability made by fifth grade pupils using calculating machines in the study of arithmetic.

However, it was also felt that this experiment would be important in providing a measuring stick with which the validity of recent claims on "streamlined" arithmetic teaching methods might be objectively evaluated.

These claims have evoked considerable comment, chiefly for two reasons: (1) a growing concern among educators over certain possible shortcomings in present-day arithmetic teaching methods which could account for (2) a decidedly negative attitude toward the study of arithmetic on the part of elementary school pupils.

Further, the possible validity of the claims is of particular significance today, when a definite relationship is becoming more clearly defined between serious technological manpower shortages and the approach to mathematics at the elementary and high school levels.



FINDINGS MADE

By Dr. Howard F. Fehr

In addition to his report, Dr. Fehr has made and authorized the following general statements concerning the use of calculating machines in teaching elementary school arithmetic:

1. Machine-taught students gain more in reasoning ability.
2. Machine-taught students gain more in computation ability.
3. Machine-taught students learn more also, because they understand machine computation as well as ordinary arithmetic.
4. The interest of students and teachers in arithmetic is heightened by use of machines.
5. The machines fit into our present culture. They give additional learning.
6. One classroom fitted with 15 machines used 7 times daily can take care of 210 pupils, i.e., each half of a 30 pupil class using its machines a half period.

Dr. Fehr further states his belief that the following elementary grades could use machines to advantage:

1. Fourth Grade—Review of addition and subtraction and study of multiplication.
2. Fifth Grade—Review of addition, subtraction, and multiplication and study of division.
3. Sixth Grade—Review of four fundamental operations and study of decimals.

The following report made by Dr. Fehr ; Dr. George McMeen, Head of the Mathematics Department, Newark State Teachers College, Newark, New Jersey ; and Dr. Max Sobel, Educational Statistician of Robert Treat Junior High School, Newark, New Jersey, is offered by the Monroe Calculating Machine Company, Inc. to the elementary mathematics teachers of the country.

The Monroe Company furnished the Educator Model Monroe Calculators for the experiment to the experimental school. Dr. Fehr supervised and planned the experiment, assisted by Dr. McMeen. Dr. Sobel scored the tests and worked out the statistics. Mr. F. Almroth, Principal of the Memorial School; Dr. L. R. Parks, Superintendent of the Cedar Grove, New Jersey, Schools; and the teachers, Mrs. A. Burger, Mrs. H. Wafle, Mrs. M. Pfizenmayer, and Mr. C. E. Knoerzer arranged for and taught the classes.

STATISTICAL APPENDICES

No experimental study can support its findings scientifically without supporting statistical facts. To simplify this report Appendices II and III have been omitted. However, to anyone who is interested we are glad to send these two statistical appendices.

A WORD OF APPRECIATION

The Monroe Company is indebted to the leading educators who supervised this study. We are also grateful to the superintendent, principal, and teachers of the experimental groups who made the arrangements and did the teaching. Finally, we are grateful to the schools in the control group and all the students for their interest and co-operation.

We hope that the teaching of arithmetic in the future will be benefited by the findings of this report and the Monroe Company nationally will be glad to cooperate with all schools who would like to reap these benefits.

THE USE OF HAND-OPERATED CALCULATING MACHINES IN LEARNING ARITHMETIC

Howard F. Fehr, George McMeen, Max Sobel

Recent reports of experiments have announced rather startling claims concerning the great amount of arithmetic learned in a rather short period of time. These researches made use of certain materials and devices. Since such great improvement in learning has not hitherto been thought possible, and since frequently such reports appear to be headlines rather than scientific fact, there is need for controlled scientific experiment to judge the values of these claims. In general there has been no royal road to improved learning in the past, only slow, careful and hard won progress. The following is a report of an experiment, scientifically designed to measure the value of the use of calculating machines in the learning of arithmetic.

In the spring of 1955, a controlled experiment on learning multiplication by a two-digit multiplier was performed by the authors of this report. The experiment was designed to test whether or not the use of calculating machines, hand operated, aid in learning both the meaning and understanding as well as developing skill in paper and pencil computation. At the end of the *two week* experiment there was no significant difference in favor of either the control group (usual learning) or the experimental group (those using machines) either in computation or in reasoning ability in arithmetic. However, a number of concomitant factors indicated that in a prolonged use of machines there might be an advantage of using machines.

These factors may be listed as (1) the enjoyment of the pupils who used machines in their arithmetic study, (2) the lack of techniques in using machines to teach arithmetic on the part of the teachers. They had to be taught not only how to use the machines, but how to teach by the use of machines. At the end

of this two week experiment the teachers in the experimental group had become enthusiastic and wished to continue using the machines. (3) The experimental groups had to learn both machine computation and paper and pencil computation in the same length of time of study as the control groups which put all this time on paper and pencil computation. Thus the experimental group, despite the heavy additional learning task, made normal gain in paper and pencil work.

To make a more satisfactory test of the value of machines in learning arithmetic a half year (4½ months) experiment was performed in the fall and winter of 1955-56. This experiment was designed to test only one hypothesis, namely:

Pupils who use calculating machines to learn arithmetic will gain significantly in paper and pencil computations and arithmetic reasoning over those who do not use the calculating machines.

In one school, four fifth-grade classes were selected as the experimental group. Two classrooms were equipped with the Monroe Educator Model hand-operated calculating machine, so that each student had an individual machine. Two classes used the same room, one class studying in the morning, the other in the afternoon session. The teachers who taught these classes were instructed how to use the machine for all four operations and told how to use the machines for arithmetic instructions. These teachers did all the teaching in the regular assigned daily period of 35 to 40 minutes. No other person instructed the classes, and no additional time was given to arithmetic instruction. A set of directions given to the teachers during the experiment is included with this report (see Appendix I). The regular textbook and syllabus were followed without any deviation, and when the study of fractions appeared the machines were not used.

The control group was scattered in four communities where the same textbook and/or syllabus was used and where the fifth grade class was comparable in I.Q. and arithmetic achievement to the four experimental classes. Both the control and experimental groups were matched very well according

to socio-economic backgrounds, i.e., types of communities, types of schools, types of occupations of parents, and quality of teachers. The textbooks used in all the classes were recently published and emphasized a meaningful approach to learning. These classes had the same length period of instruction each day, and used such materials and mechanical aids as they were accustomed to use in regular teaching. However, they did not use calculating machines in any manner. All classes were given the Beta Otis Quick Scoring Mental Test, and pretested with Form J, Intermediate Arithmetic Stanford Achievement Test. At the conclusion of the experiment all classes were tested with Form K, Stanford Intermediate Arithmetic Achievement Test.

The following tables summarize the test statistics of the experiment.

TABLE I

Means of Control Groups

	1	2	3	4
I.Q.	110.68	110.52	107.83	107.70
Pretest Computation	4.71	5.10	4.56	4.67
Post Test Computation	5.47	5.32	5.30	5.96
Gain in Computation	.76 (8 mo.)	.22 (2 mo.)	.74 (7 mo.)	1.29 (13 mo.)*
Pretest Reasoning	5.80	5.79	5.84	5.40
Post Test Reasoning	6.18	5.98	6.25	6.30
Gain in Reasoning	.38 (4 mo.)	.19 (2 mo.)	.41 (4 mo.)	.90 (9 mo.)*
N	23	21	22	26

(The above means are given in terms of grade norms.)

*Class 4 of the control group, upon investigation was found to have two full time practice teachers in addition to the regular teacher and to have spent much extra time on sixth grade work in decimals and fractions contrary to the agreement of the experiment. There were a number of psychologically disturbed children in this class who contributed to the poor showing on the initial tests and were eliminated from the final test. Nevertheless, the statistics of this class were retained in this final report.

TABLE II**Means of Experimental Groups**

	1	2	3	4
I.Q.	107.18	112.50	111.74	107.84
Pretest Computation	4.70	4.87	4.26	4.56
Post Test Computation	5.57	5.55	5.48	5.32
Gains in Computation	.87 (9 mo.)	.68 (7 mo.)	1.22 (12 mo.)*	.76 (8 mo.)
Pretest Reasoning	5.49	5.57	4.88	5.43
Post Test Reasoning	6.21	6.28	6.03	6.40
Gains in Reasoning	.72 (7 mo.)	.71 (7 mo.)	1.15 (12 mo.)*	.97 (10 mo.)
N	25	20	19	23

*1 year = 10 mo. of school work. Hence 1.2 = 12 school months.

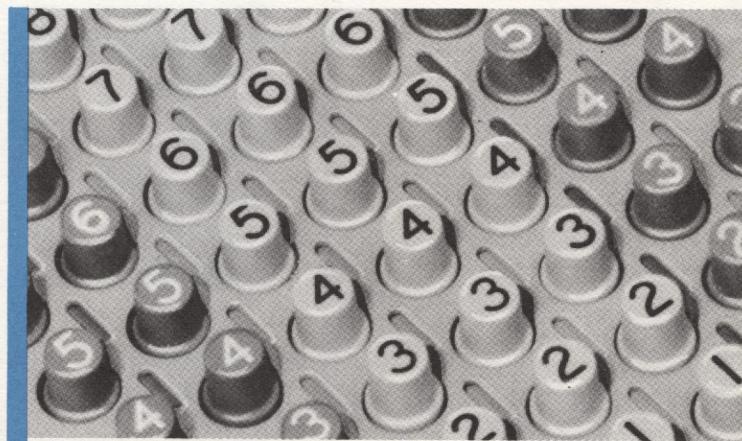


TABLE III**Mean Gains by Groups****COMPUTATION**

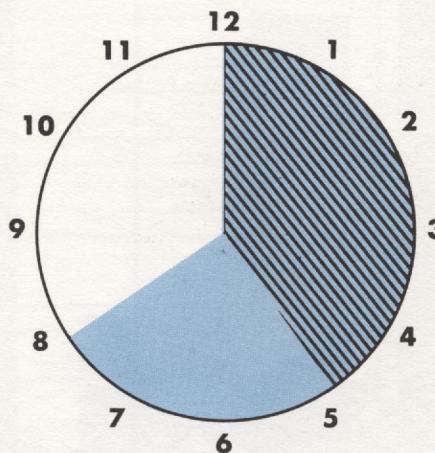
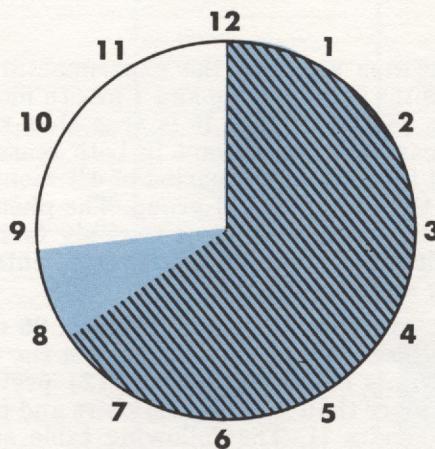
Control (N = 92)
Experimental (N = 87)

	Pretest	Post test	Gain
Control (N = 92)	4.75	5.53	.78
Experimental (N = 87)	4.61	5.48	.87

REASONING

Control (N = 92)
Experimental (N = 87)

	Pretest	Post test	Gain
Control (N = 92)	5.69	6.18	.49
Experimental (N = 87)	5.46	6.23	.77

**CONTROL****EXPERIMENTAL**

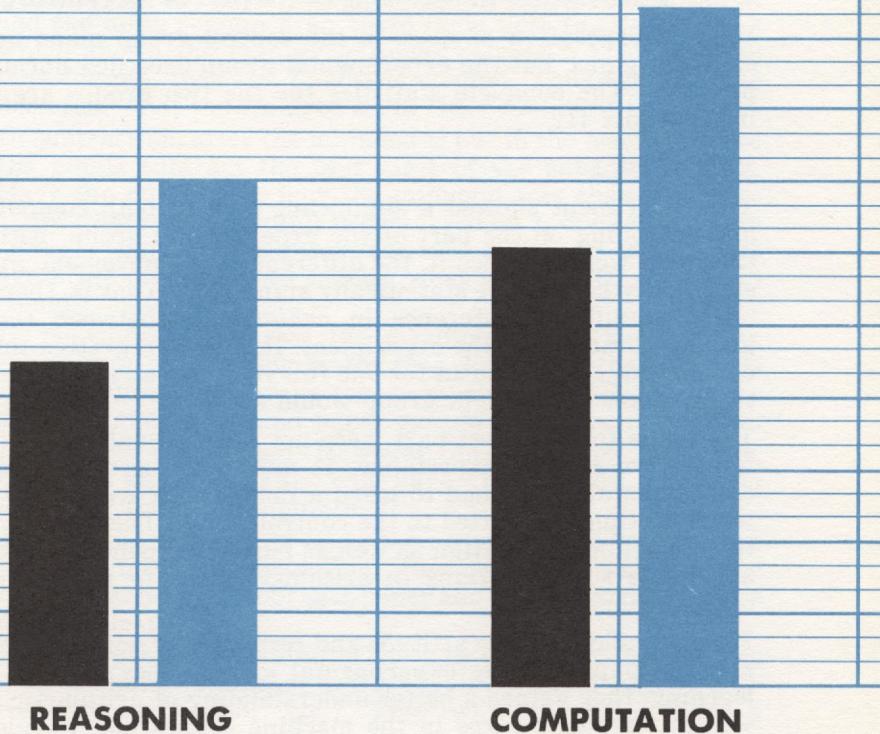
We thus see that the experimental group gained 3 more months in reasoning and 1 month more in computation than the control group. It is true that the experimental group began at a lower point in both reasoning and computation, but the gains for a period of $4\frac{1}{2}$ months are greatly in favor of the experimental group. The phenomenal gain of class 4 of the control group is the only factor that prevents a significant advantage to the experimental group in both reasoning and computation.

As a further means of evidence, 25 matched pairs of pupils were selected at random to meet the criteria (1) I.Q. within 5 points of each other and (2) pretest scores not to differ by more than .3. These 25 pairs and their scores are listed in Appendix II. The following table summarizes the results.



TABLE IV**Mean Scores of 25 Matched Pairs**

	Pretest	Post test			
	Reasoning	Computation	Reasoning	Computation	I.Q.
Experimental	5.57	4.67	6.27	5.61	107.92
Control	5.56	4.69	6.01	5.30	107.56
Gains of Experimental			.70	.94	
Gains of Control			.45	.61	
Difference in Favor of Experimental group			.25	.33	

10 MONTHS**9 MONTHS****8 MONTHS****7 MONTHS****6 MONTHS****5 MONTHS****4 MONTHS****3 MONTHS****2 MONTHS****1 MONTH****REASONING****COMPUTATION****CONTROL****EXPERIMENTAL**

This is a significant gain in favor of the experimental group at the .95 level of confidence. All the evidence therefore points in favor of sustaining the hypothesis. It is to be noted, however, that the accomplishments of each group at the end of the experiment do not show a significant difference. (Again due in part to the great gain made by class 4 in the control group.)

Looking at the results of the experimental group only we can say that in a period of 4½ months, these classes made gains of 9, 7, 12 and 8 school months of arithmetic learning in computation and 7, 7, 12, and 10 months in reasoning. This is to be compared with corresponding gains of 8, 2, 7, and 13 months in computation and 4, 2, 4, and 9 months in reasoning on the part of the control group.

With the exception of class 4, the control group made normal expected gains, but the experimental group exceeded normal expectancy. The complete statistics for the two groups are given in Appendix III.

SUMMARY

The experiment showed a significant *gain* in both computation and reasoning on the part of the experimental group. Although the gains were significant, the difference in achievement was not sufficiently large to be statistically significant. That is, there was not a significant difference in *achievement* between the two groups at the end of the experiment. It is to be regretted that the experiment could not run for one full year, but all indications are that the machine-taught group would excel.

The gains for the most part were not phenomenal, but within a level of reasonable expectancy. It must also be noted that the experimental group had to learn a double task within the same teaching time as allotted to the control group. They learned how to do machine calculation as well as paper and pencil calculation, and made superior gains in arithmetic both in reasoning and computation.

More significant is the attitude and responses of both the teachers and the pupils in the experimental group. They enjoyed their learning, they gained a better understanding of arithmetic, there was an *esprit de corps* in the machine classes not prevalent in ordinary classes. The values attributed to the use of the machines are recorded in the frank letters from these experimental teachers. These letters are included as Appendix IV.

It is safe to say that the proper use of calculating machines in learning arithmetic over an extended period of time results in gaining greater ability in both computation and in reasoning than the learning that is done without the use of these machines.

APPENDIX I

Suggestions for using the calculating machine to aid paper and pencil computation

1. Be sure to use the machines continually, at least 3 days and preferably 4 days each week. The quicker machine skill is obtained, the more it can be used to aid the understanding and developing of skill in computation.
2. The machines can be used to check paper computation. But, also do the reverse, that is, have the children calculate by machine, and then check the result by paper and pencil.
3. In using the machines for column addition, have the children add the units column first. Have them note the partial sum which shows the number of tens "carried." Then add the tens column, then the hundreds column. Thus the machine does just what the children do in their computation.
4. In subtraction, after the minuend is put in the machine, have the pupils subtract the unit digit of the subtrahend first. Have the pupils note how the minuend was changed, especially where the tens digit is decreased by 1, due to exchange or borrowing. Then subtract the tens digit, and so on. Thus again the machine does exactly what we do with paper and pencil.
5. In multiplication, stress the meaning of the shift of the carriage as multiplying by the tens digit, then the hundreds digit, and so on. Always try as much as possible to make machine and pencil and paper calculation agree in method.
6. Do not insist on speed. However, insist on ease, sureness, security, knowing. This will have the greatest effect on becoming *correct* computers.
7. Always make the paper and pencil work a little harder than previous machine calculation. This shows the value of the machine and also encourages paper and pencil learning before machine learning.
8. Don't forget to have children check by paper and pencil (also interchanging multiplier and multiplicand, multiplying quotient by the divisor, etc.). They will not always have a machine to check.
9. Do not omit problems. They are as important as mere computation. However, use the machine to solve problems.
10. Be sure to think of new problems to interest pupils as they get to be expert with the machine. Finding an average is a good one, as it involves finding a sum and then dividing the answer.

APPENDIX IV

"Our children have gained a better understanding of arithmetic through the use of the machines; our teachers have been spurred to critically evaluate their procedures in teaching arithmetic and in analyzing the material assigned to the grade level."

Principal, Memorial School

"The stimulus of the machines created a challenge in the child not only to learn the machine operations, but also to show that his own written arithmetic would be as correct as the work he did on the machine.

"The class developed an *esprit de corps* about using the machines. The quick students helped the slower ones and everyone seemed eager to maintain a high class average.

"At this age level the machine was a good disciplinary device. The children not only looked forward to using the machines, but soon learned that instructions must be listened to and carefully followed.

"I feel that the machines have a place in the curriculum as they would create a great desire to learn arithmetic better."

Teacher

"I am very happy to list some of the reactions of both students and teachers relative to our participation in the calculating machine experiment:

1. Pupils had fun using machines.
2. Greater interest in doing arithmetic.
3. Carrying was better understood.
4. Pupils found out what tables they didn't know.
5. Realized that multiplication was adding a number a certain number of times—machine recorded.
6. Realized that division was subtracting divisor from dividend as many times as possible—machine recording the number of times.
7. Enjoyed using machine to check their written work.
8. Place value was better understood."

Teacher



"In reply to your request for my reaction to the use of the machines, I feel that they were worthwhile in many respects. They proved a challenge to the pupils and revealed their ability to grasp the technicalities involved to operate the machines skillfully. It made place value more meaningful and resulted in a higher rate of accuracy on daily assignments.

"You might be interested to have the reactions of several of my pupils:

'They were a help on checking work.'

'They made us think faster.'

'They made me feel able to run a machine.'

'It was an easy way to check pencil and paper work.'

'It was a lot of fun just to work a machine.'

'It made me want to improve in arithmetic.'

'It gave the teacher extra time while we checked our own work.' "

Teacher

"The children through the use of the machines learned the placement of numbers very quickly. Interest was stimulated and arithmetic was made more enjoyable.

"The comments made by the children after using the machines were:

'They made arithmetic fun.'

'Helped us in learning our times tables.'

'Helped us in long division especially two-figured divisors.'

'They help us in carrying.'

'The machines were easy to use and we will know how to use the machines in later life.' "

Teacher



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